MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 1, 2019/2020

ENT4086 – DIAGNOSTIC TECHNOLOGY

(NE)

17 OCTOBER 2019
02:30 p.m. - 04:30 p.m.
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This Question paper consists of 7 pages with 4 Questions only.
2. Attempt **ALL FOUR** questions. The distribution of the marks for each question is given.
3. Please print all your answers in the Answer Booklet provided.
4. Please refer to page 7 for the Appendix on IR absorptions table.

QUESTION 1

(a) (i) With the aid of a suitable diagram, explain the operating principles of scanning tunneling microscopy (STM).

[3+5 marks]

(ii) Discuss the **TWO(2)** elements that give rise to the atomic-scale resolution of the STM.

[6 marks]

(b) (i) With the aid of a schematic diagram, describe the working principles of x-ray diffraction (XRD) based on Bragg's Law.

[3+5 marks]

(ii) Explain briefly why Cu (copper) K_α radiation is commonly used as the x-ray source in XRD.

[3 marks]

QUESTION 2

(a) (i) What are the properties that a magnetic tip should have for *high resolution* and *high sensitivity* detection, respectively, in magnetic force microscopy (MFM)?

[6 marks]

(ii) Describe the trade-off relationships between the *spatial resolution* and *magnetic force sensitivity* in MFM imaging.

[5 marks]

(iii) Suggest **ONE(1)** possible approach that can be adopted in order to avoid the tip-induced reorientation of magnetization in measuring soft magnetic sample using MFM. Justify your suggestion.

[1+4 marks]

(b) (i) Discuss briefly **TWO(2)** effects induced by ion bombardment that may contribute to the deterioration of depth resolution in Auger depth profiling.

[6 marks]

(ii) Suggest **THREE(3)** methods that can be applied to improve the depth resolution.

[3 marks]

Continued...

QUESTION 3

(a) **Figures Q3(a)(i)** and **Q3(a)(ii)** show the ion scattering spectroscopy (ISS) spectra of the topmost layer of a sample surface analysed using different primary ions of helium ions (He^+) and neon ions (Ne^+), respectively, with similar ion energy of 3 keV. Answer the following:
Given the atomic number, Z, of He(Z=2), O(Z=8), Ne(Z=10), Al(Z=13), V(Z=23), Mo(Z=42), and Te(Z=52).

(i) Analyse the spectra in **Figures Q3(a)(i)** and **Q3(a)(ii)** in the context of *peak observed* and *relative concentration*, respectively.

[6 marks]

(ii) Explain briefly why the peaks are overlapping at 2500 eV in **Figure Q3(a)(i)** when analysed using the He^+ ions.

[3 marks]

(iii) Explain briefly why some of the peaks are missing at low energy region in **Figure Q3(a)(ii)** when analysed using the Ne^+ ions.

[3 marks]

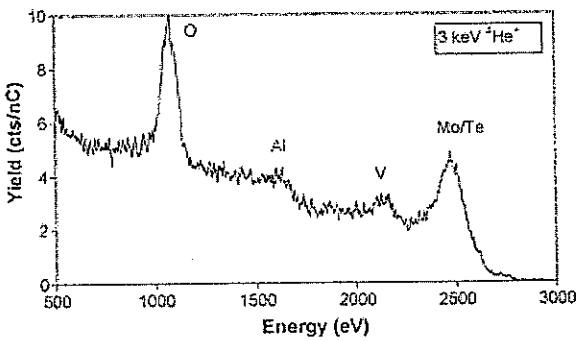

Figure Q3(a)(i)

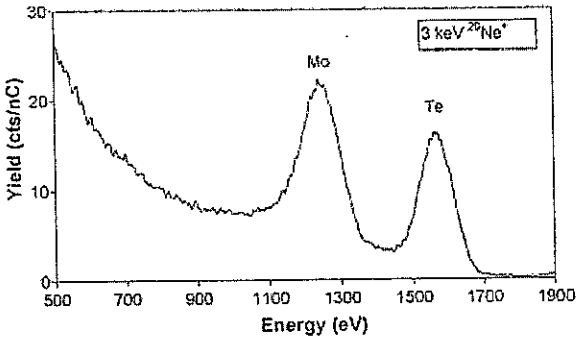

Figure Q3(a)(ii)

(Courtesy of H.R.J. ter Veen et al., 2009)

(b) (i) State the selection rules for *IR (infrared) active* and *Raman active* molecular vibrations, respectively.

[2 marks]

(ii) **Figure Q3(b)** shows the schematics of three different molecular vibration modes: ν_1, ν_2 and ν_3. State the responsiveness of each of the vibrational modes to *IR* and/or *Raman*.

[3 marks]

Continued...

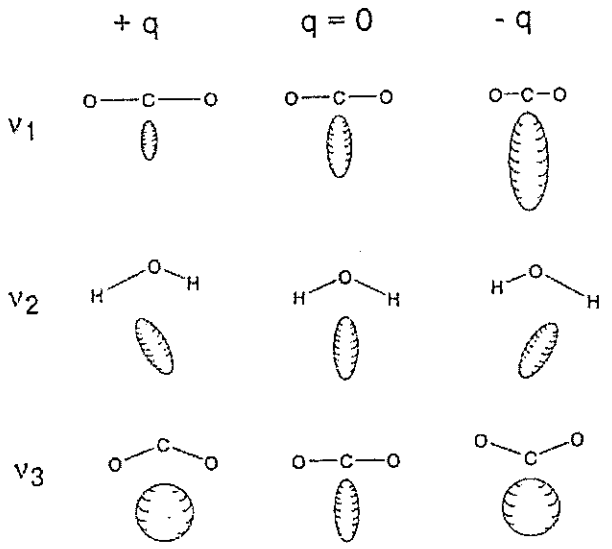

Figure Q3(b)

(c) **Figure Q3(c)** shows the IR spectrum of an alkane (saturated hydrocarbons). Analyse the spectrum in the context of *types of bond observed* and *relative amount of bonds*, respectively.

[8 marks]

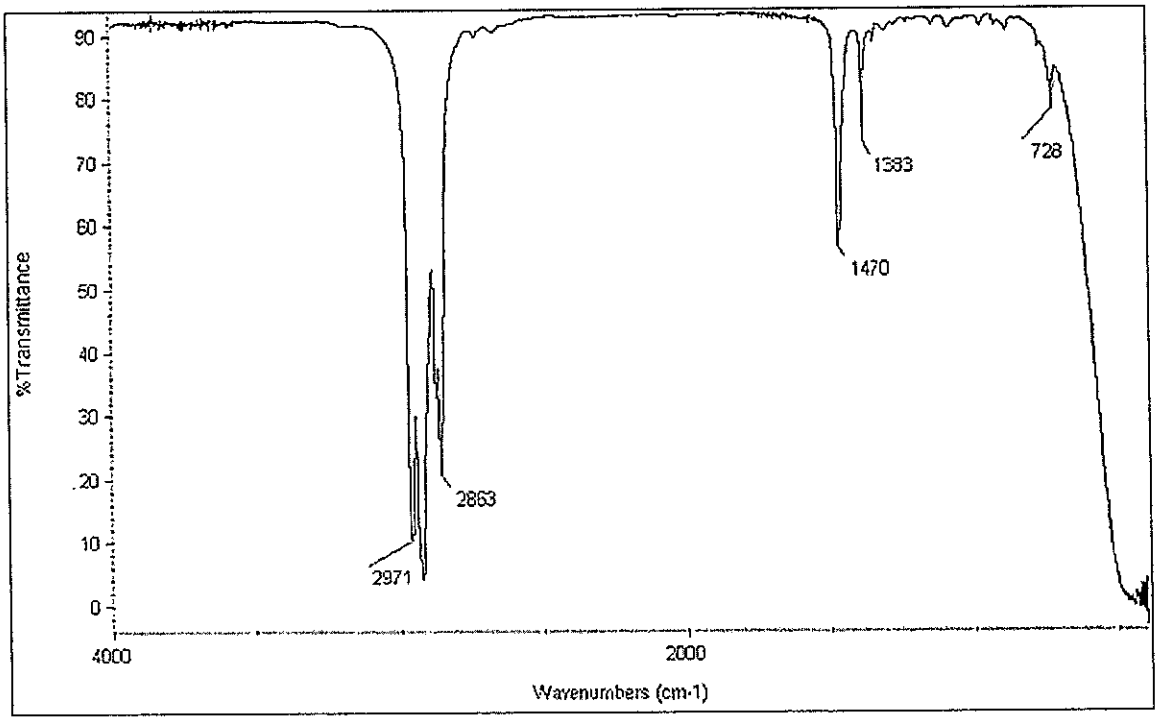

Figure Q3(c)
(Courtesy of Organic Chemistry, CU Boulder)

Continued...

QUESTION 4

(a) **Figures Q4(a)(i) and Q4(a)(ii)** show the x-ray diffraction (XRD) pattern and scanning electron microscopy (SEM) image of a cadmium oxide (CdO) nanoparticles sample, respectively. Answer the following:

(i) Analyse the XRD pattern in the contexts of *peaks observed* and *crystallinity* of the CdO nanoparticles, respectively.

[6 marks]

(ii) Given that the XRD measurement was carried out using Cu (copper) K_α radiation of 1.542 Å and full width at half maximum (FHWM) of the (220) peak is 0.8195°, determine the average particle size using the Debye Scherrer's equation.

[3 marks]

(iii) Evaluate the surface morphology of the sample in the contexts of *shape* and *size* of the CdO nanoparticles, respectively.

[3 marks]

(iv) Comment on the consistency of the particle sizes obtained from **(ii)** and **(iii)** above.

[2 marks]

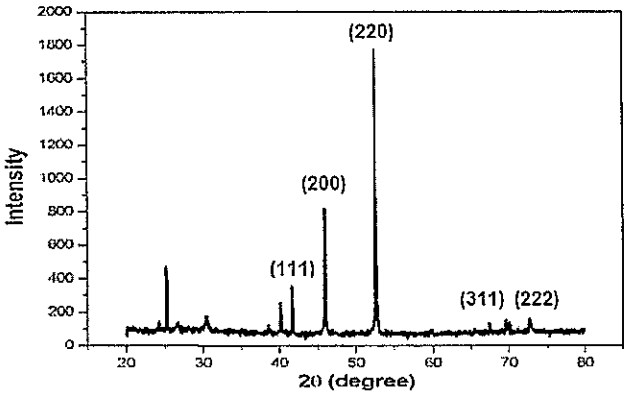

Figure Q4(a)(i)

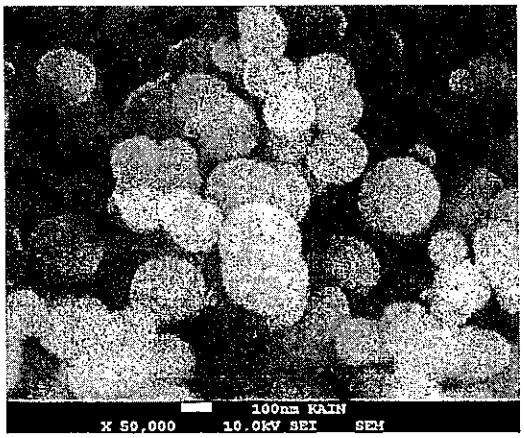

Figure Q4(a)(ii)

(Courtesy of A.S. Aldwayyan et al., 2013)

(b) **Figure Q4(b)** shows the layer structure of a sample which is comprised of a 150 nm-thick nickel oxide (NiO)-silicon oxide (SiO_2) composite film deposited on a Si wafer substrate. The sample is characterised using Rutherford backscattering spectroscopy (RBS) to determine the film composition. Answer the following:

(i) Draw the RBS spectrum, *intensity* as a function of *backscattering energy*, which you will expect to obtain from the measurement. Label the peaks to indicate the elements clearly.
Given the atomic number, Z, for O(Z=8), Si(Z=14), and Ni(Z=28).

[5 marks]

Continued...

(ii) Justify the formation of your RBS spectrum in **(i)** associates with the *position* and *energy span* of the peaks, respectively.

[6 marks]

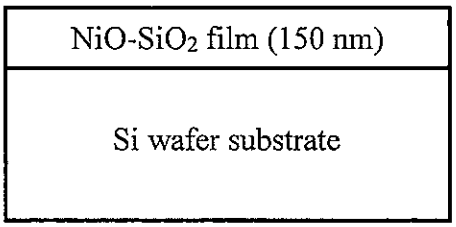

Figure Q4(b)

Continued...

APPENDIX

Table of Characteristic IR Absorptions

frequency, cm^{-1}	*bond*	*functional group*
3640–3610 (s, sh)	O–H stretch, free hydroxyl	alcohols, phenols
3500–3200 (s,b)	O–H stretch, H–bonded	alcohols, phenols
3400–3250 (m)	N–H stretch	1°, 2° amines, amides
3300–2500 (m)	O–H stretch	carboxylic acids
3330–3270 (n, s)	–C≡C–H: C–H stretch	alkynes (terminal)
3100–3000 (s)	C–H stretch	aromatics
3100–3000 (m)	=C–H stretch	alkenes
3000–2850 (m)	C–H stretch	alkanes
2830–2695 (m)	H–C=O: C–H stretch	aldehydes
2260–2210 (v)	C≡N stretch	nitriles
2260–2100 (w)	–C≡C– stretch	alkynes
1760–1665 (s)	C=O stretch	carbonyls (general)
1760–1690 (s)	C=O stretch	carboxylic acids
1750–1735 (s)	C=O stretch	esters, saturated aliphatic
1740–1720 (s)	C=O stretch	aldehydes, saturated aliphatic
1730–1715 (s)	C=O stretch	α, β–unsaturated esters
1715 (s)	C=O stretch	ketones, saturated aliphatic
1710–1665 (s)	C=O stretch	α, β–unsaturated aldehydes, ketones
1680–1640 (m)	–C=C– stretch	alkenes
1650–1580 (m)	N–H bend	1° amines
1600–1585 (m)	C–C stretch (in–ring)	aromatics
1550–1475 (s)	N–O asymmetric stretch	nitro compounds
1500–1400 (m)	C–C stretch (in–ring)	aromatics
1470–1450 (m)	C–H bend	alkanes
1370–1350 (m)	C–H rock	alkanes
1360–1290 (m)	N–O symmetric stretch	nitro compounds
1335–1250 (s)	C–N stretch	aromatic amines
1320–1000 (s)	C–O stretch	alcohols, carboxylic acids, esters, ethers
1300–1150 (m)	C–H wag (–CH_2X)	alkyl halides
1250–1020 (m)	C–N stretch	aliphatic amines
1000–650 (s)	=C–H bend	alkenes
950–910 (m)	O–H bend	carboxylic acids
910–665 (s, b)	N–H wag	1°, 2° amines
900–675 (s)	C–H "oop"	aromatics
850–550 (m)	C–Cl stretch	alkyl halides
725–720 (m)	C–H rock	alkanes
700–610 (b, s)	–C≡C–H: C–H bend	alkynes
690–515 (m)	C–Br stretch	alkyl halides

m=medium, w=weak, s=strong, n=narrow, b=broad, sh=sharp

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